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Integrated Modeling of Overall Productivity

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Outline of presentation

Introduction

Farming system concept

Case study result – Climate, Crop and economic modeling

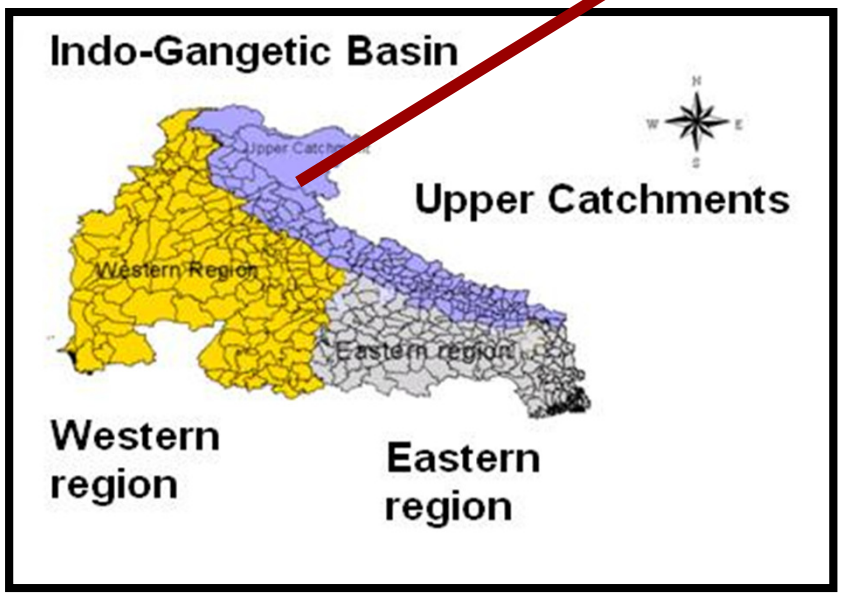
Integrated modeling framework

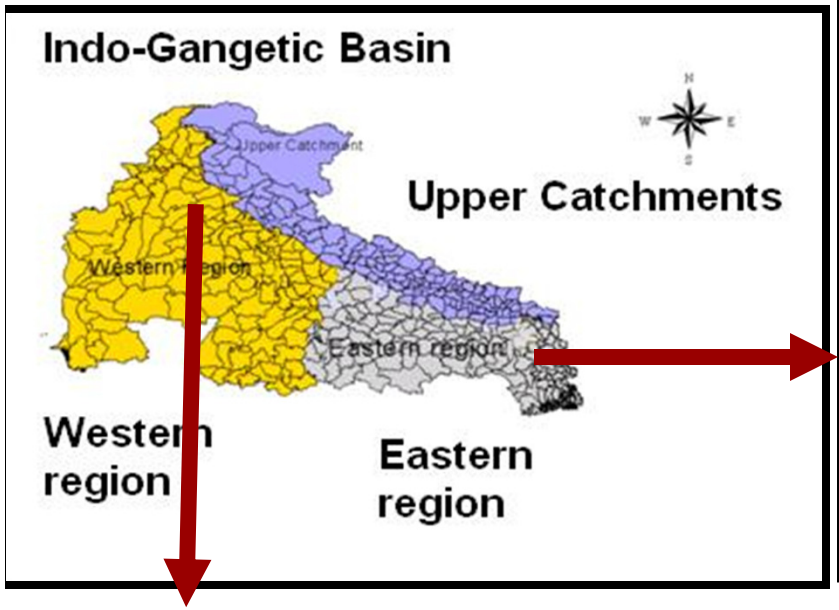
Climate change and Indo-Gangetic Basin

- Climate change impacts are increasingly visible in IGB with greater variability of the monsoon
- An increase in the occurrence of extreme weather events such as heat waves and intense precipitation that affect agricultural production drastically and thereby the food security and livelihoods of many small and marginal farmers, particularly in the more stress-prone regions of the central and eastern IGB
- Earlier estimates indicated that if the current trends continue until 2050, the yields of irrigated crops in IGB are projected to decrease significantly – maize by 17 %, wheat by 12 % and rice by 10 % - as a result of climate change induced water stress (Aggarwal et al. 2009)

Indo-Gangetic Basin – Food Basket of South Asia

- Low productivity (Rice-Wheat 4-5 t/ha)
- Poor investment in infrastructure
- Medium-high precipitation (1000-2000 to > 2000 mm)
- High potential for cold water fisheries and livestock
- Degradation of Land and water resources
- Low human capital - high out-migration
- Downstream environmental constraints

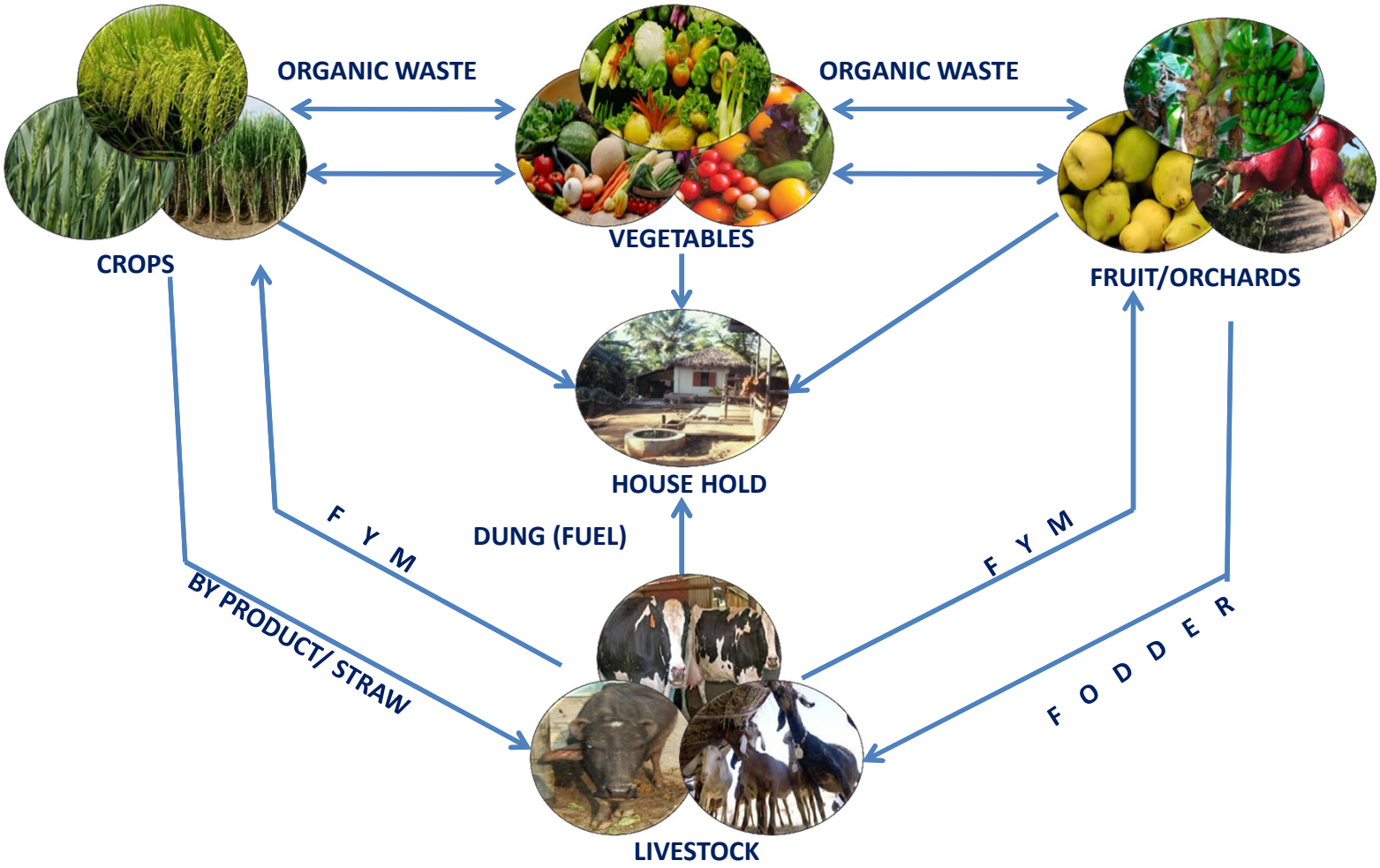




- **Low Productivity** (R-W:4-8 t/ha) - Food deficit region
- **Low investment in infrastructure**
- Medium - High rainfall (1000-2000 to > 2000 mm)
- **Underutilization of ground water (< 20 %)**
- **Very few developed irrigation network**
- High risk of flooding, poor drainage and moderate drought
- Out-migration of laborers

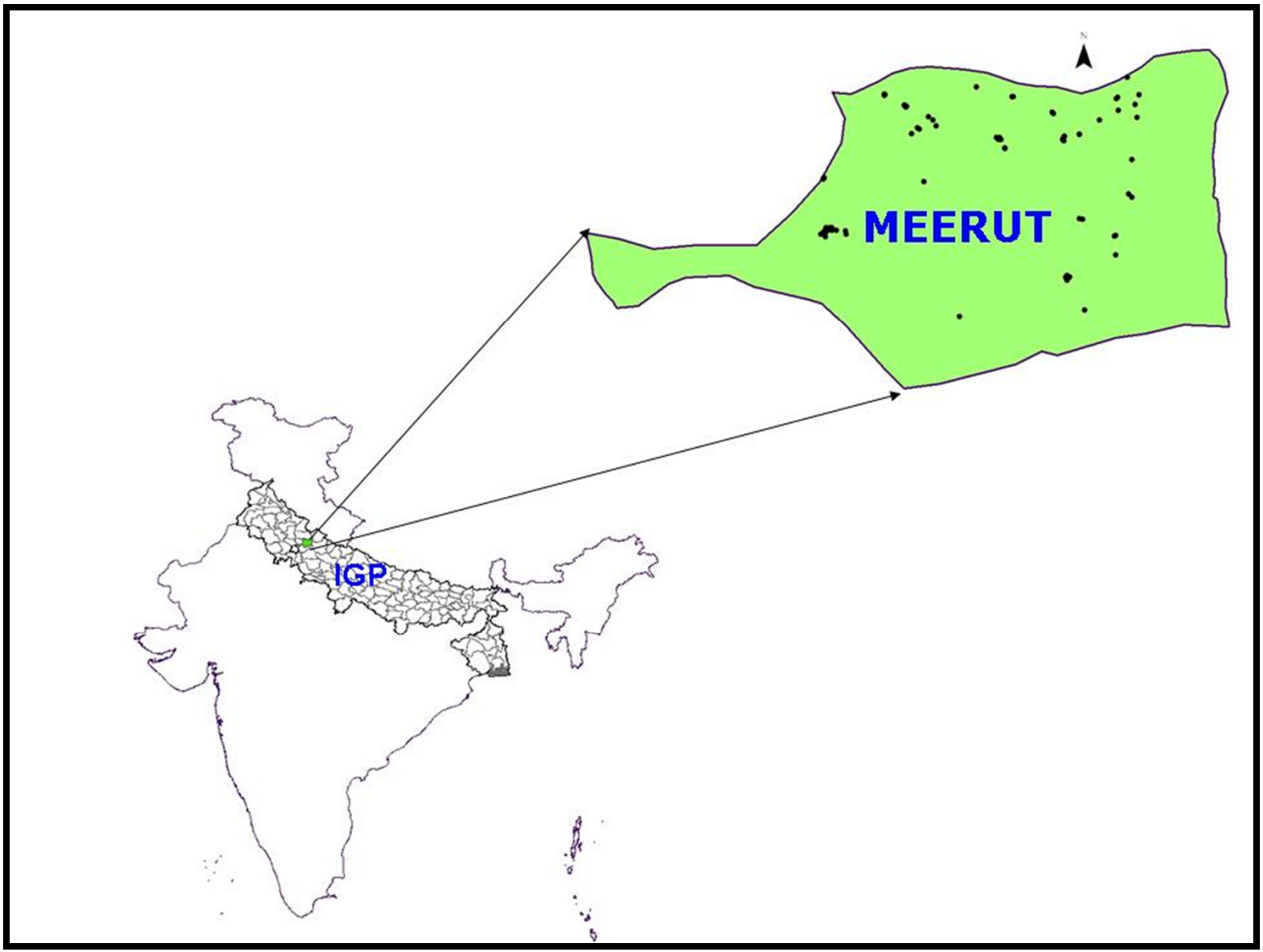
- **High Productivity** (R-W: 8-12 t/ha) - Food surplus region
- **High investment in infrastructure**
- Higher inputs of agro-chemicals
- Low - Medium rainfall (500-1000 to 1000-2000 mm)
- **Over exploitation of ground water (>80 %)**
- **Well developed irrigated network**
- Severe to moderate drought prone areas
- In-migration of labour

What is Farming System?



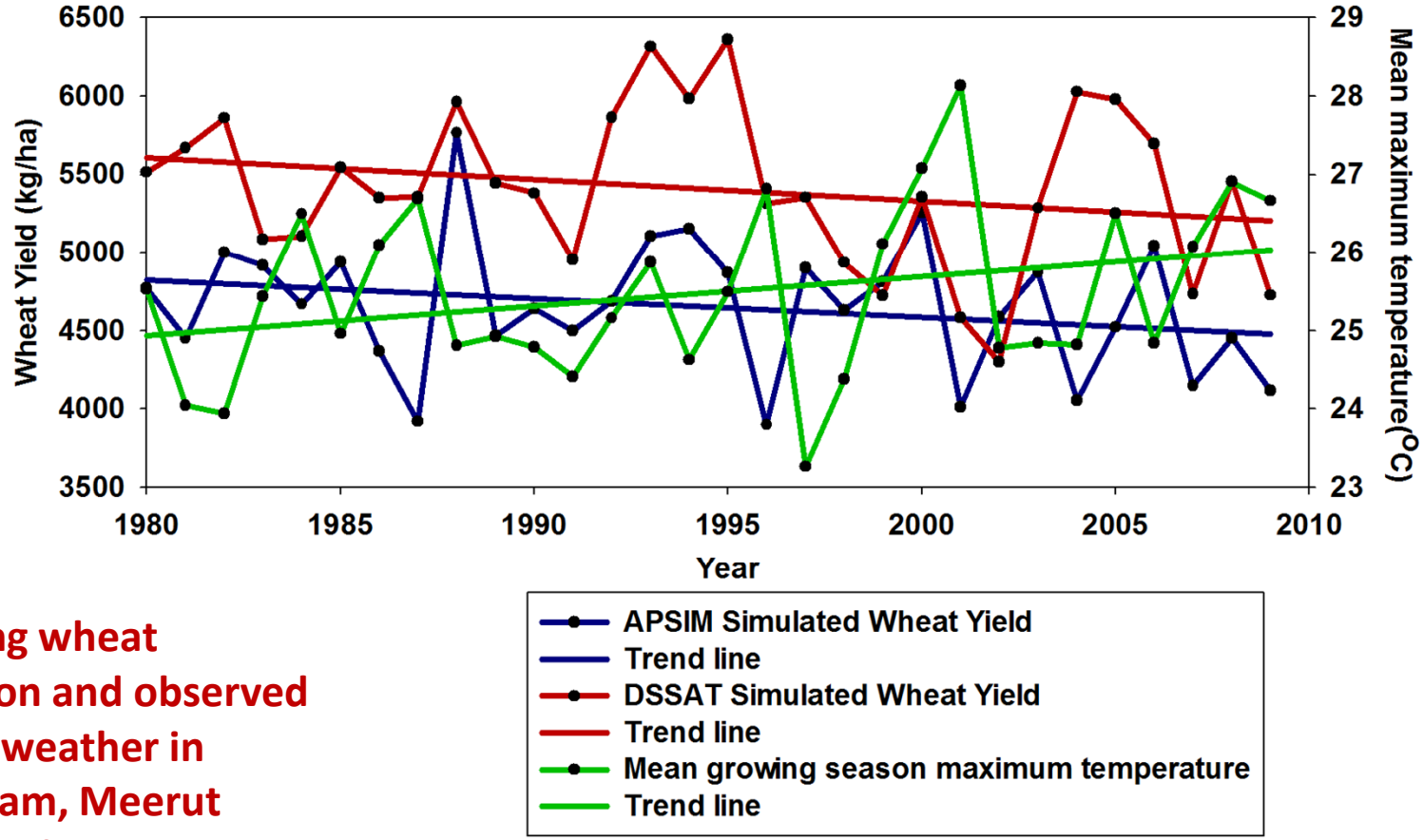
Meerut District, Uttar Pradesh

Study site



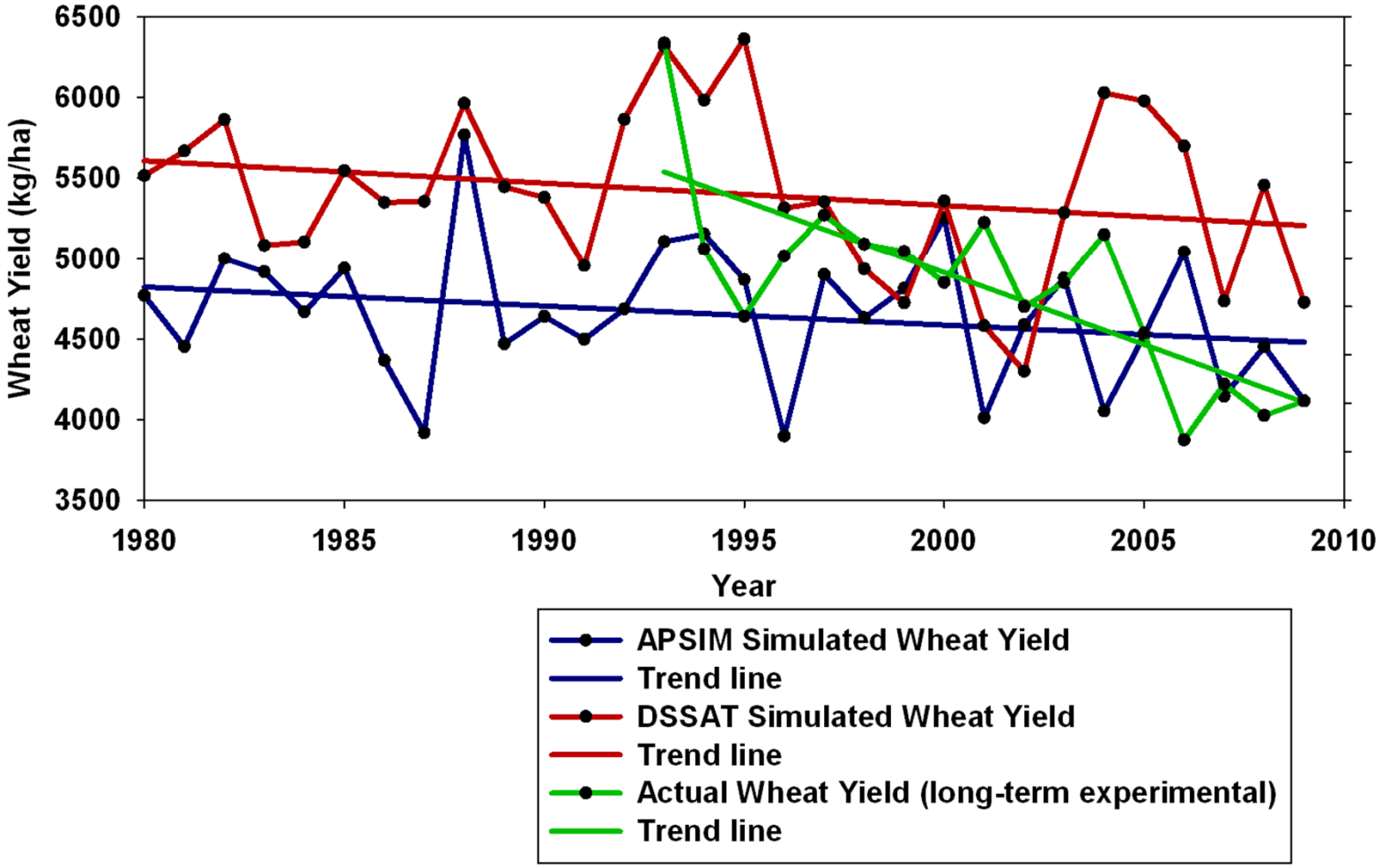
Understanding Current Agro-climatic Variability

Wheat Yield vs Mean Growing Season Mean maximum Temperature

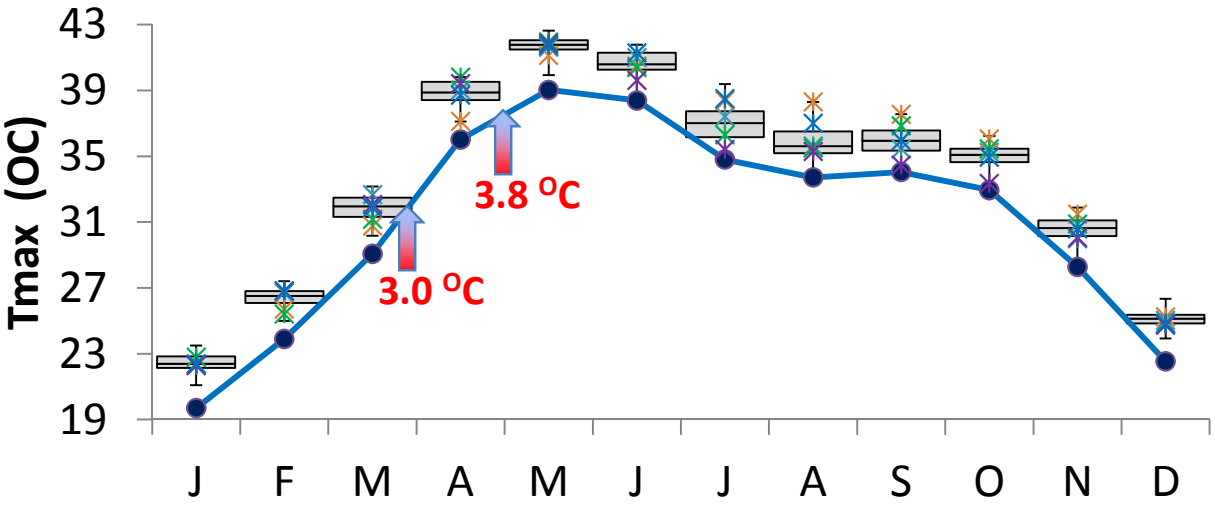


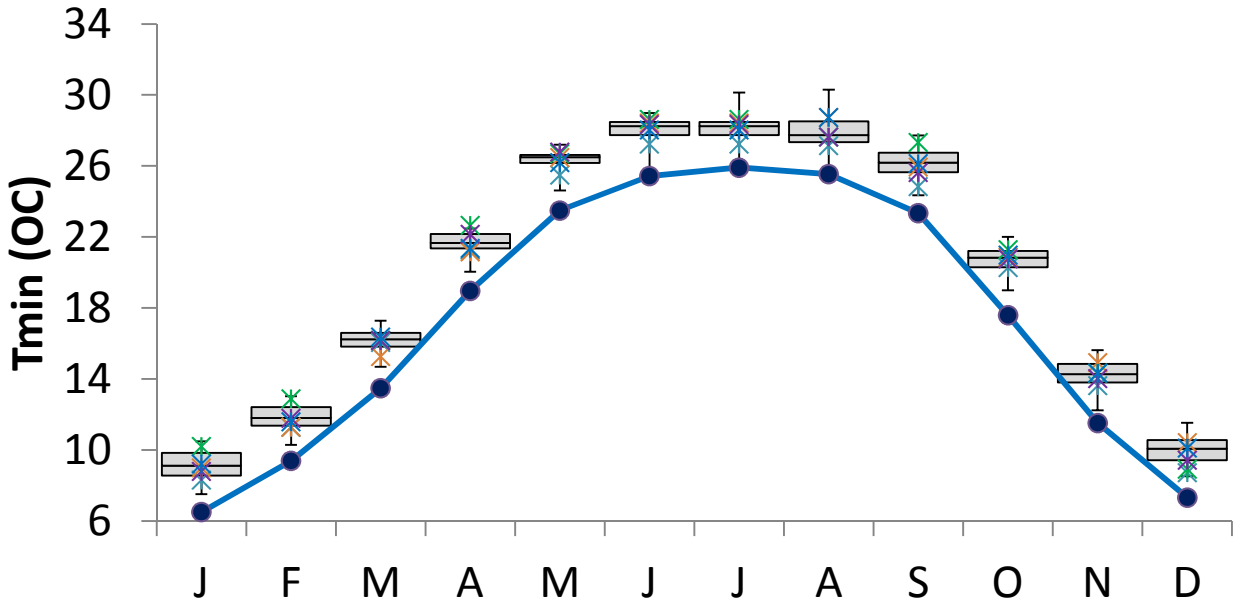
Examining wheat production and observed baseline weather in Modipuram, Meerut District, India

Comparison between simulated (APSIM & DSSAT) and actual wheat yield



Future Scenarios- Temperature

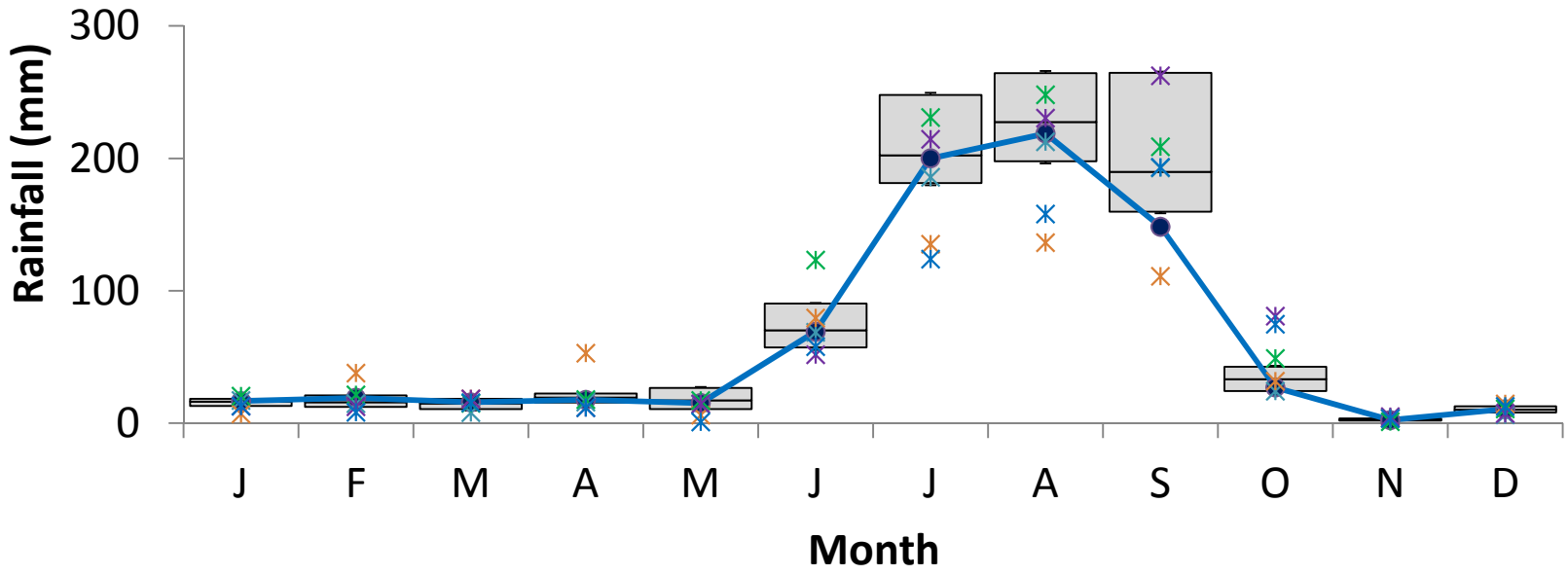




All GCMs predicted higher monthly mean maximum and minimum temperatures during the mid-century period 2040-2069 under RCP8.5 compared to baseline (1980-2010). All the five targeted GCMs predicted more or less same nature of projections.

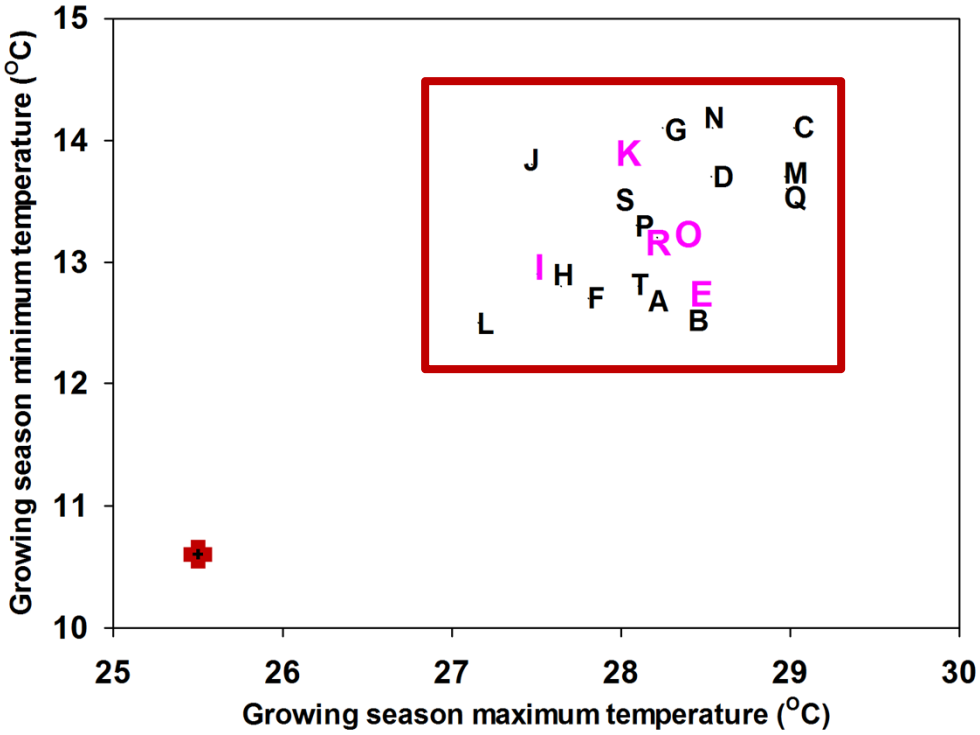
Baseline (blue line and dots) and future (box-and-whiskers) monthly and seasonal mean maximum and minimum temperature for Modipuram, India, in the 2050s under RCP8.5. The stars (different colors) represents 5 "target" GCMs (CCSM4, GFDL-ESM2M, HadGEM2-ES, MIROC5, MPI-ESM-MR).

Future scenarios - Rainfall



Baseline (blue line and dots) and future (box-and-whiskers) monthly mean precipitation for Modipuram, India, in the 2050s under RCP8.5. The stars (different colors) represents 5 "target" GCMs (CCSM4, GFDL-ESM2M, HadGEM2-ES, MIROC5, MPI-ESM-MR).

Uncertainty in GCM Ensemble of Climate Change Projections



Uncertainties in maximum and minimum temperature

Wheat growing season (December-April) mean maximum and minimum temperature projected by 20 CMIP5 climate models (denoted by letters A-T) for Modipuram, Meerut District, India, in the 2050s under the high-emissions RCP8.5 scenario. The red square represents baseline conditions. The pink letters shows the GCMs used for AgMIP home stretch.

Crop Modeling- Sentinel data source and treatment details

Long term data on nutrient management experiment (1993-2010)

Years : 2007-08 (calibration) & 2008-09 (validation)

Soil data : Profile-wise (0-150 cm) bulk density, OC, NO_3, NH_4, EC & pH, LL15, DUL, SAT and Soil texture

Crop data : Phenology, LAI, and Biomass partitioning at different phenology, Grain and straw yield

Variety : PBW343

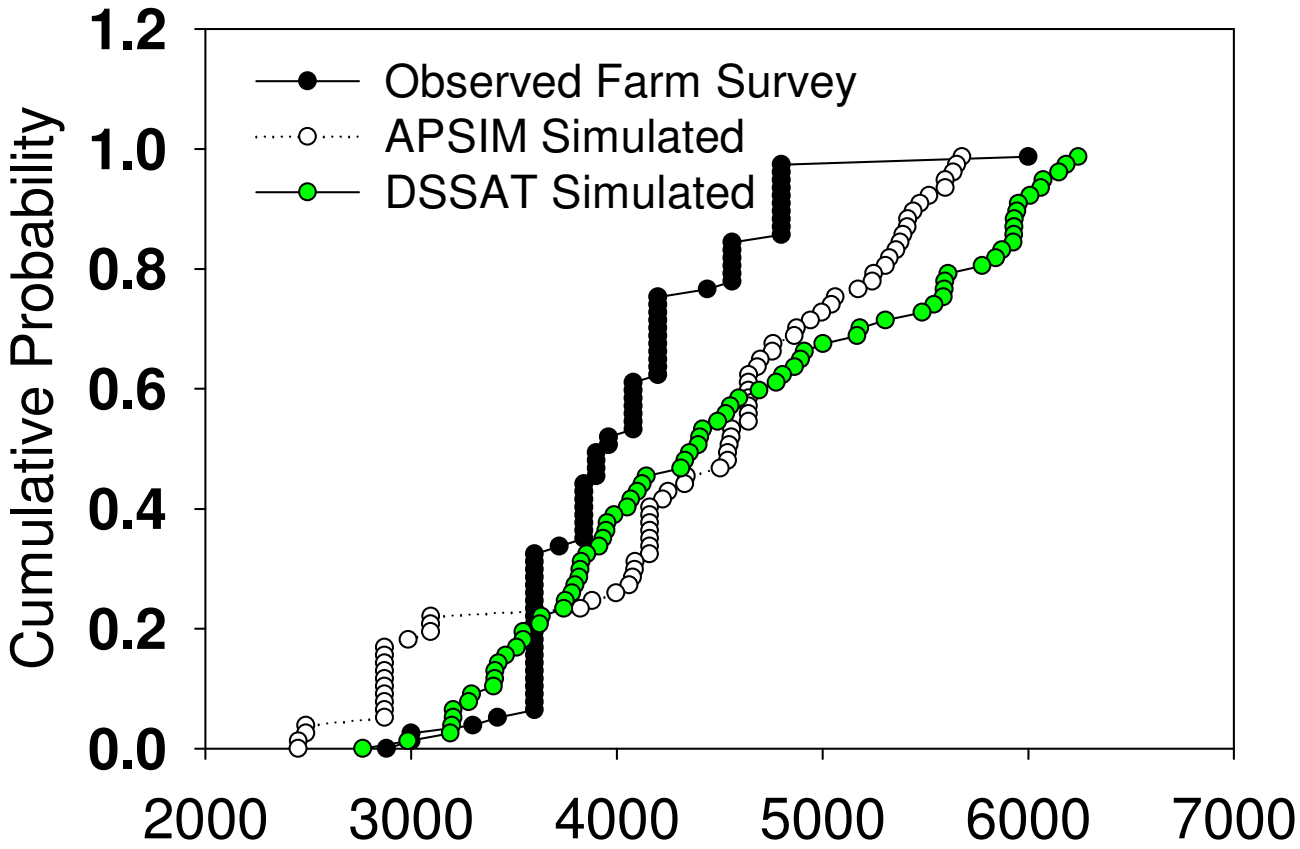
N:P:K (kg/ha) : 120-60-40

Irrigation: 5 irrigations : CRI, PI, Anthesis, Milking & Dough

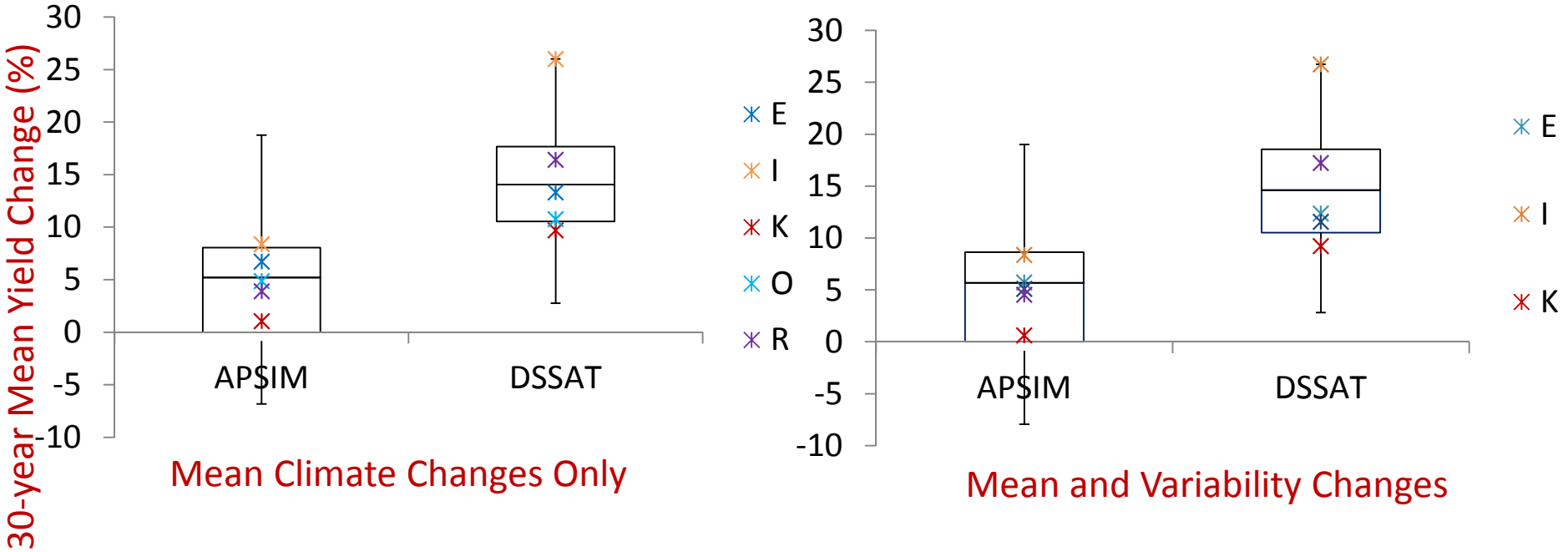
Observed variability in the farm data

- Crop Models used – APSIM & DSSAT
- Crop - Wheat
- Farm survey data of 76 rice-wheat farms
- Wide variability in dates of sowing - 17th October to 3rd January
- Date of Harvest – 10th April - 17th May
- Five cultivars – PBW223, PBW243,WL502, PBW343, UP232
- No. of irrigations – 3,4 & 5
- Variability in N, P and K applications

CDF- Comparison of APSIM and DSSAT simulated wheat yield and observed farm yield

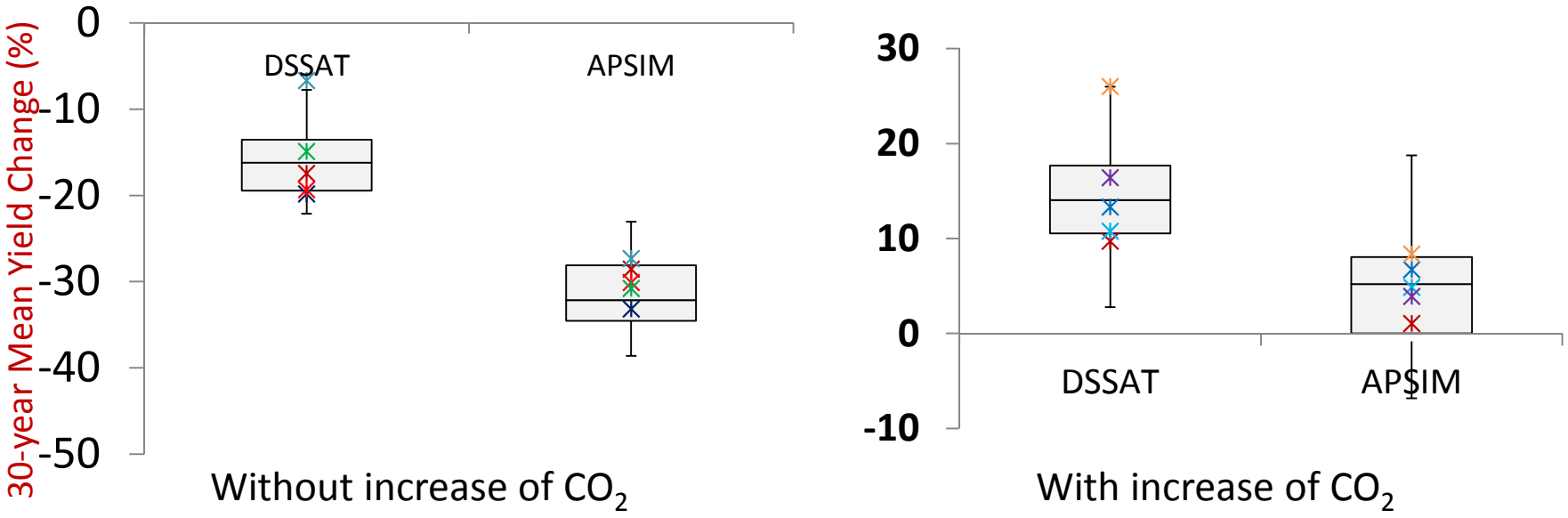


Projections of climate impacts on wheat yield



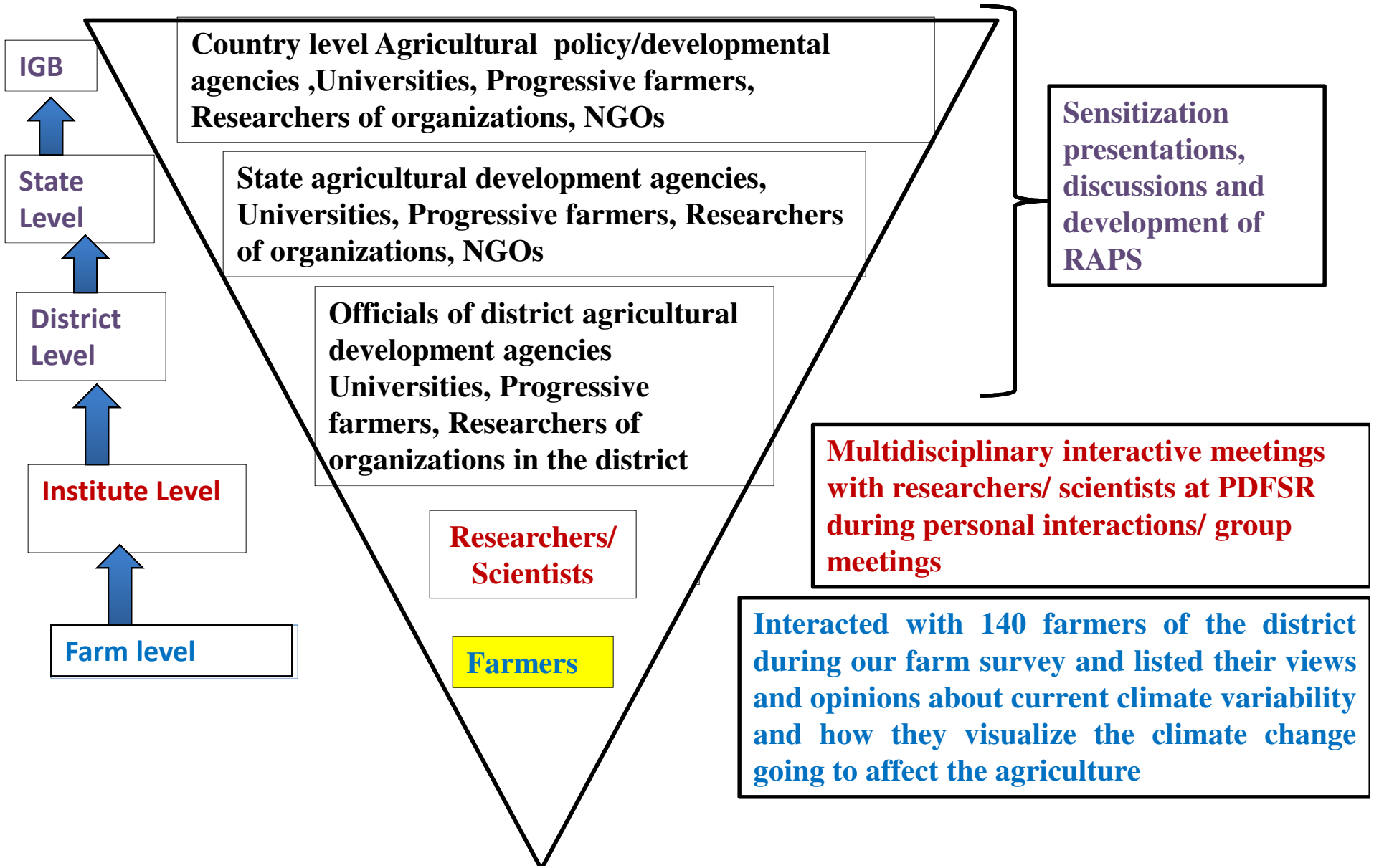
Box-and-whisker plot showing distribution of mean yield changes (%) from 20 GCM-based scenarios using (right) mean-only "delta" scenarios, and (left) scenarios including both mean and variability changes. It also compares the results from APSIM & DSSAT simulation outputs. The five models that are the focus of the core simulations are represented as different color stars.

Projections of climate impacts on wheat yield – Comparison between incorporating increase of CO_2 and without increase of CO_2 effect (mean climate change only)



Box-and-whisker plot showing distribution of mean yield changes (%) from 20 GCM-based scenarios using mean-only "delta" scenarios. It also compares the results from APSIM & DSSAT simulation outputs with and without incorporating the CO_2 effect. The five models that are the focus of the core simulations are represented as different color stars.

Interactions with Stakeholders- Methodology/approach



AgMIP The Agricultural Model Intercomparison and Improvement Project

RAPs Narrative

- Climate change has adverse impact on wheat production.
- Though government adopts long-term and short-term policy measures, wheat production costs increase substantially.
- Imports are inadequate to meet domestic demand and assured price support policy also is inadequate to raise the wheat production to meet domestic demand.
- Hence, government liberalizes wheat imports, invests in food chain logistics and boost R&D for developing new wheat cultivars to boost domestic production of wheat.

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GAINS AND LOSSES – Model Inter-comparison (5 Climate Scenarios) AND 2 CROP MODELS (APSIM & DSSAT) – TOA-MD results

Climate Scenario	Future simulated yield (kg/farm)	Time averaged relative yield	Predicted future yield (kg/farm)	Gainers (%)	Gains (%)	Losses (%)	Net Losses (%)	Crop Model used
E	1879	1.01	1706	50.01	29.86	30.61	0.75	APSIM
E	3176	1.19	2007	58.09	41.85	27.02	-14.83	DSSAT
I	1688	0.91	1532	43.64	24.03	36.30	12.27	APSIM
I	3425	1.28	2164	60.92	46.72	25.83	-20.90	DSSAT
K	1737	0.93	1577	45.82	25.71	33.95	8.25	APSIM
K	3213	1.19	2009	58.44	42.58	27.04	-15.54	DSSAT
O	1819	0.98	1651	48.31	28.03	31.83	3.80	APSIM
O	3179	1.19	2009	58.09	41.97	27.17	-14.80	DSSAT
R	1743	0.94	1582	45.83	25.72	33.94	8.23	APSIM
R	3218	1.20	2033	58.61	42.70	26.77	-15.93	DSSAT

Base period yield (kg/farm) – 1688; Base period simulated (kg/farm) APSIM-1860;DSSAT-1672)

(E-CCSM4, I-GFDL-ESM2M, K-HadGEM2-ES, O-MIROC5, R-MPI-ESM-MR).

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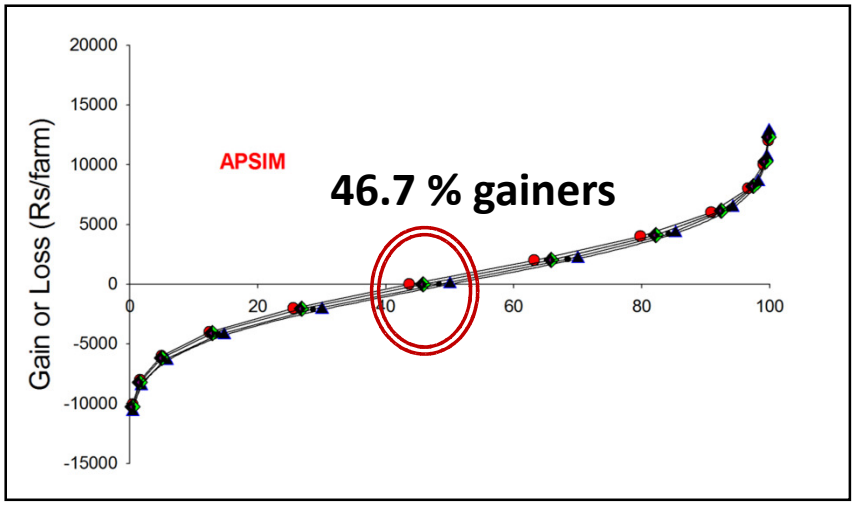
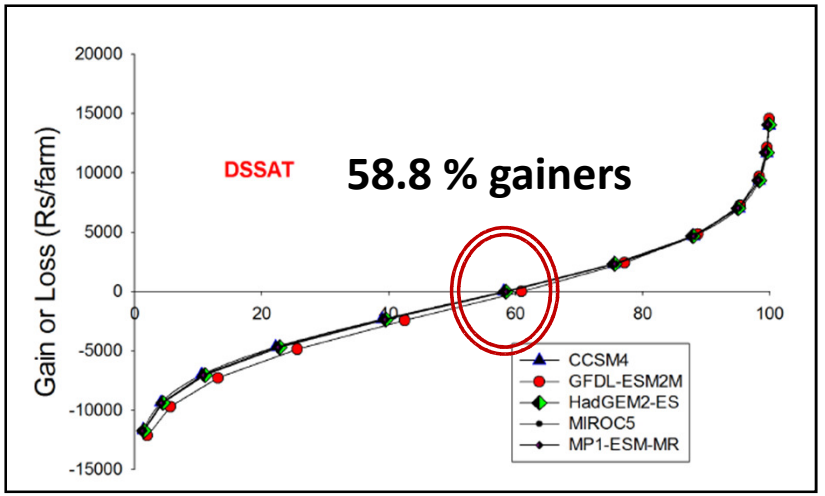
Comparison of Gains and losses through DSSAT and APSIM under 5-GCM projected climate scenarios.

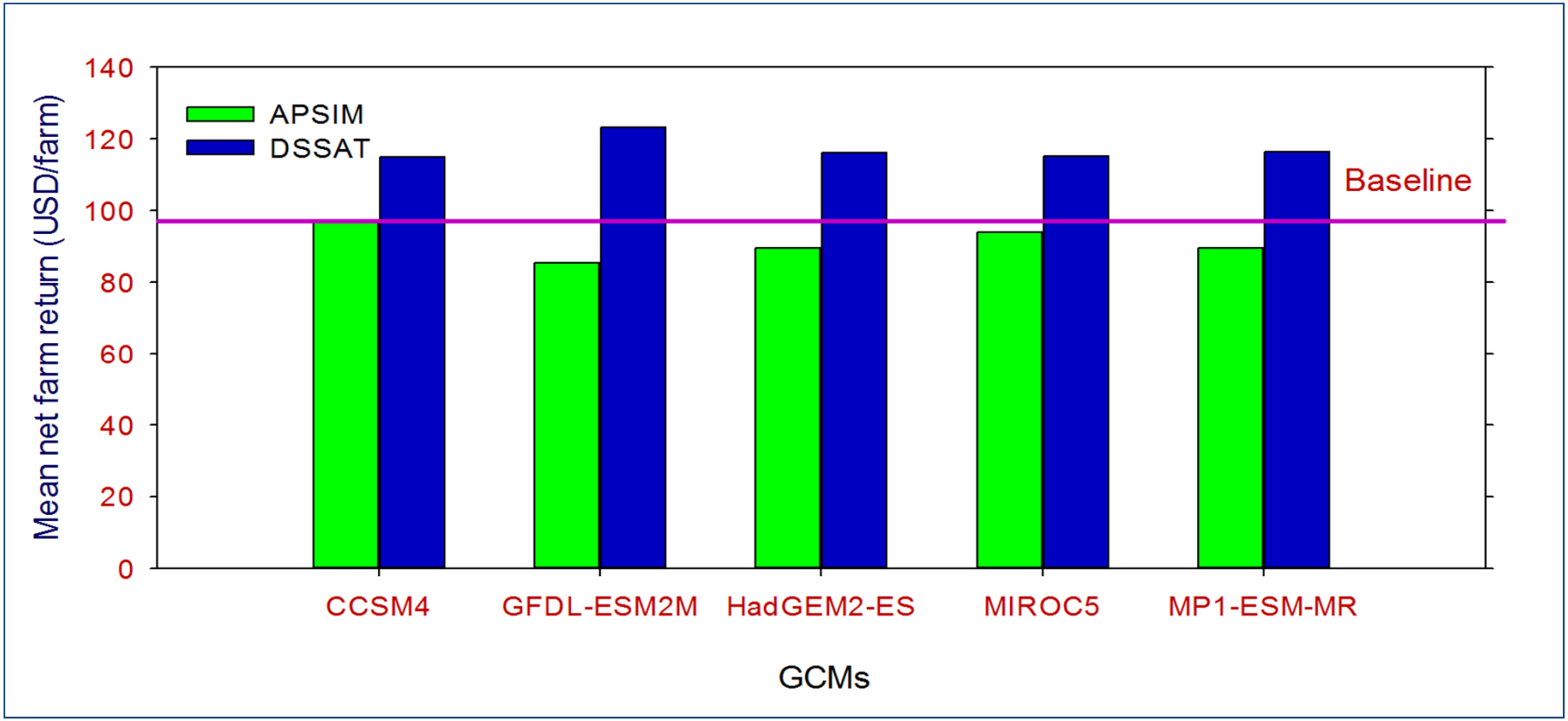




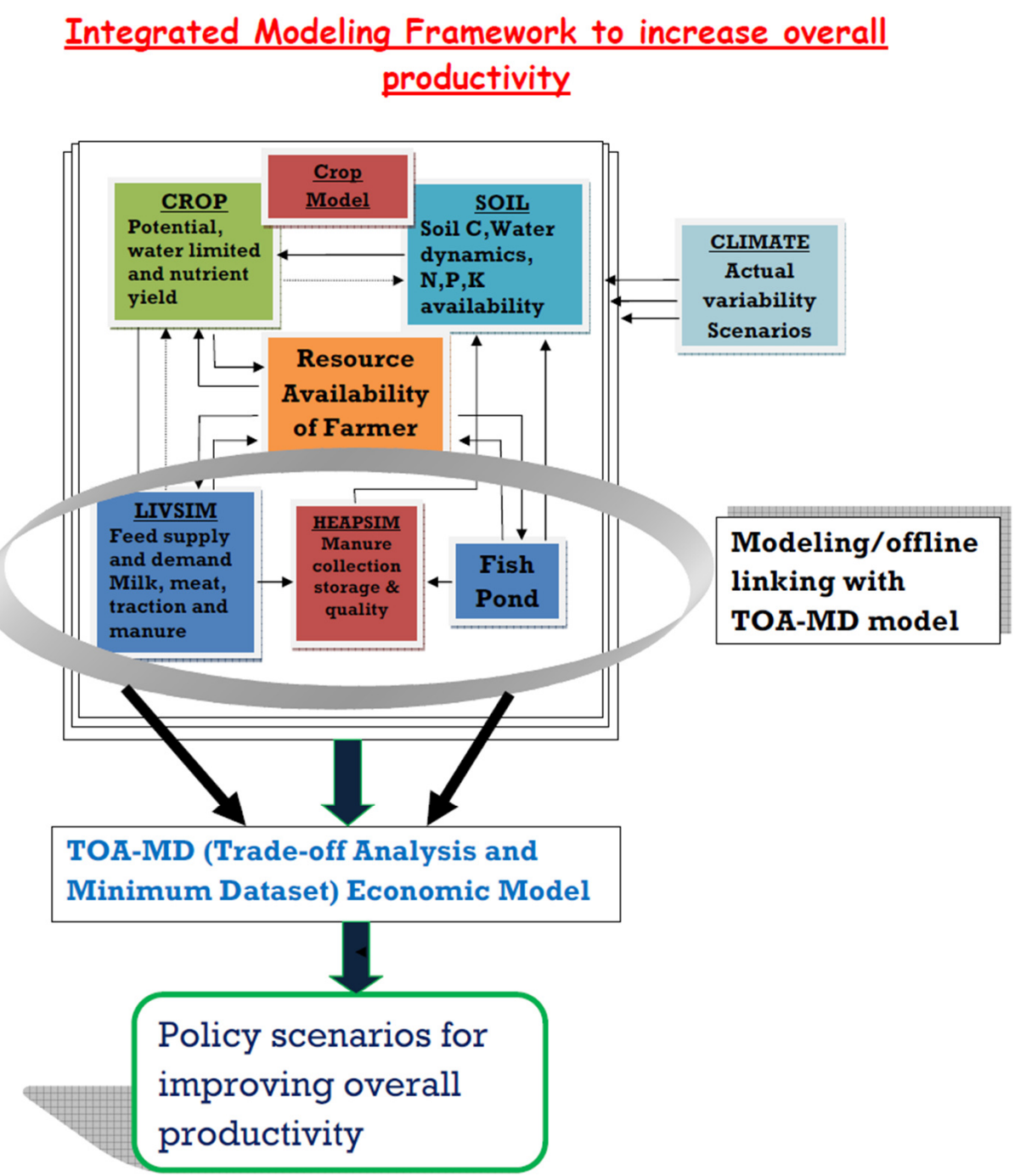
DSSAT simulated slightly higher optimistic scenarios compared to APSIM during mid-century period 2040-2069 under RCP8.5.

Mean net farm return (USD/farm)

Comparisons of Projected Mean net farm returns under different GCM scenarios through APSIM and DSSAT



Need of the hour



Thank you